Scaling Near-surface Atmosphere and Surface Wave Influences on Radar Propagation over the Sea

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LONG-TERM GOALS

Improve models for describing near horizon radar propagation by proper specification of the near-surface atmosphere refractivity gradients and wind influenced surface roughness.

OBJECTIVES

To evaluate Monin-Obukhov surface-layer scaling for describing near surface gradients of refractivity and on characterizing the surface roughness for radar backscatter and propagation within evaporation ducting.

APPROACH

This overall approach is to perform special joint analyses/interpretations on near-surface refractive gradients, turbulent transport, and surface wave data obtained from buoys and vessels during a coordinated one-month experiment. The experiment was coordinated by the Naval Surface Warfare Center, Dahlgren Division (NSWCDD). Other field collection participants were groups from the SPAWAR Systems Center-San Diego (SSC-San Diego), the Johns Hopkins University, Applied Physics Laboratory (JHU/APL) and the Naval Postgraduate School (NPS). The experiment is called Wallops'98. Defining features of the experiment were its coordinated surface layer and surface and radar field strength (NSWC-DD) and backscatter inversion (SPANDAR-SSC-San Diego) measurements. There are necessary steps; formation of a merged data set for multi-group collection, estimating near-surface refraction, and Atmospheric forcing and wave descriptions for clutter

Approach: Formation of merged data set

There will be a formation of a data set for analyses/interpretation which consists of the atmospheric and radar data sets. The merged in situ data set will used to document environmental conditions and to evaluate surface-layer scaling for the description of radar propagation. It will be based on both long time-series mean measurements of the near-surface refraction and wave conditions (buoy measurements) and short time-series measurements of turbulence and near-surface profiles (on the instrumented vessel "Chessie" and the catamaran). The buoy mean air and surface data will be used with bulk aerodynamic methods (e.g. LKB) to obtain velocity, temperature, humidity, and buoyancy

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scaling parameters. The vessel turbulent data will be from a sonic anemometer and the scaling parameters will be obtained by applying the inertial-dissipation methods.

Approach: surface-layer refraction gradients

The near-surface refractivity profile is most frequently described in terms of the evaporation duct height or strength. Existing surface-layer scaling theory leads to the refractivity profile (evaporation duct height) being estimated from single level measurements of turbulent and/or mean quantities. Surface layer flux-profile scaling theory yields a general empirical expression for the near-surface gradients, dX/dz, or evaporation duct height, Z*, in terms of velocity, temperature, humidity, and buoyancy scaling parameters (u*, T*, q*, g/T), i.e.

$$dX/dz \text{ or } Z^* = F(u^*, T^*, q^*, g/T).$$

The existing approach may not be valid for all thermal stability and does not include the effect of waves, at all. There is evidence from the Catamaran data and that existing empirical expressions requires more investigation for the influence of buoyancy on mixing, particularly for the case when the air is warmer than the water, and of long waves on low level profile shapes. Shown in figure 1 are comparisons of observed and predicted profiles. They don't agree possibly because of wave influence.

The turbulent scaling parameters (u*,T*,q*) can be estimated from Chessie-sonic measured turbulent intensities, themselves, or by inferring them from air-surface difference measurements using existing flux-profile relationships. The first approach would provide the most representative results of near-surface gradients, other than impractical direct profile measurements, since the important mixing process is implicit in the measured data. Analyses of the sonic (Chessie) turbulent data will be critical in evaluation and verification of the validity of the of bulk methods for the near-shore region.

Approach: Atmospheric forcing and wave descriptions for clutter

This is particularly important to interpreting the SSC-San Diego obtained SPANDAR data. The wind stress is the mechanical forcing by the wind on the ocean surface. As such, the turbulence-controlled wind stress is an intermediate link between the atmosphere and the ocean for interpreting radar-measured features. Interpretations will be based on spatial patterns within the SPANDAR fields and combined near-surface refractivity gradient and temporal/spatial wind stress estimated from ship and buoy in situ data. The relation between radar clutter and the wind stress and measured roughness elements may depend on swell. The swell dominated regime is not understood relative to influence of momentum flux on surface backscatter. The NPS Wallops'98 deployed Data Well wave-rider provided two-dimensional wave statistics for wind waves and swell. These two-dimensional descriptions of surface waves will be merged with the wind stress scaled capillary waves for interpretations. The equilibrium wave model information will be used to extrapolate to shorter waves.

WORK COMPLETED

The combined collection of in situ and remote (radar) data occurred off Wallops Island, VA from March to April 1998. Table 1 is a summary of Wallops'98 combined atmospheric and ocean surface data set where NPS obtained data are denoted by bold x's.

Completing the merging of NPS and other groups (NSWCDD, JHU/APL) surface-layer and surface wave data and with other groups (NSWCDD, SSC-San Diego) radar data were begun in FY98 and will be near completion in the FY99 analysis/interpretation phase.

All field collection participants began exchanging buoy and ship data immediately after the experiment for comparison and merging purposes. Final arrangements for collaboration on the merged data was made at a recent one-day participant's workshop were held on 22 July at NSWCDD, Dahlgren, VA. Initial comparisons, the application of bulk models to estimate evaporation duct and surface fluxes, and the filling of "gaps" have begun with all data sets.

Table 1. Wallops'98 Atmospheric Boundary Layer Merged Data

Platform Type/ Platform	**Buoy**			**Vessel**	
	NPS Mean Met	NPS 2-D wave	NSWCDD Endeco	JHU/APL Chessie	NSWC-DD Sea Lion
Mean Air					
Vector Wind	X		X	X	X
Temperature	X		X	X	X
Humidity	X		X	X	X
Pressure	X		X	X	X
Turbulent Air					
Wind				X[1]	
Temperature				X[1]	
Profiles					
Near-surface (T,RH)				X[2]	
Mixed-layer (T,RH,P)				X[3]	
Surface Properties					
SST interfacial (IR)	X			X[2]	
SST bulk(thermistor)	X		X		X
2-D wave/swell		X	X		

[1] NPS sonic
[2] JHU/APL catamaran

RESULTS

Preliminary results from merged NPS buoy and vessel (Chessie) acquired times series of in situ surface-layer meteorological, surface temperature and, wave data over the 4 March to 3 April period appear in Figure 2. These results show the wide range of stratification conditions is evident in the figure. Also shown are calculated evaporation duct heights for the month-long period. Focus days based on other groups' activities are identified by color coded marks in the top panel. The radar periods of interest are for daytime hours of these days. The wave buoy time series in the bottom panel of Figure 2 clearly shows a data gap for a 8 ½ day 15-23 March period, due to a still unknown acquisition system writing errors. Gaps that occurred in the other buoy time series are not apparent in Figure 2 because of the resolution. The occurrence of such data gaps in MET-Buoy data for one of the focus days, appear in higher resolution. The gaps in NPS meteorology buoy data were caused by the radio link being degraded by near-surface refraction and onboard computer's acquisition intermittence.

One objective is that wave influence on the near-surface gradients can be revealed in this combined data set, once interpreted, and that this is related to influence on radar propagation.

IMPACT/APPLICATIONS

The potential future impact is for understanding the influence of waves on the overlying scalar profiles and the better prediction of near-horizon radar propagation.

TRANSITIONS

These results are being used to improve operational models now used in fleet.

RELATED PROJECTS

The ONR Electro-Optical Processes and Coastal Environment is a closely related projects because it also requires improved models of near-surface gradients, affecting optical wavelengths.

IN-HOUSE/OUT-OF-HOUSE RATIOS

Over a two year period, one the data collection and a second the analyses/interpretation, 75% percent of the work is done by a NPS personnel. The other 25% was performed by a contractor (McKinney Technology) for support with buoy design and deployment.

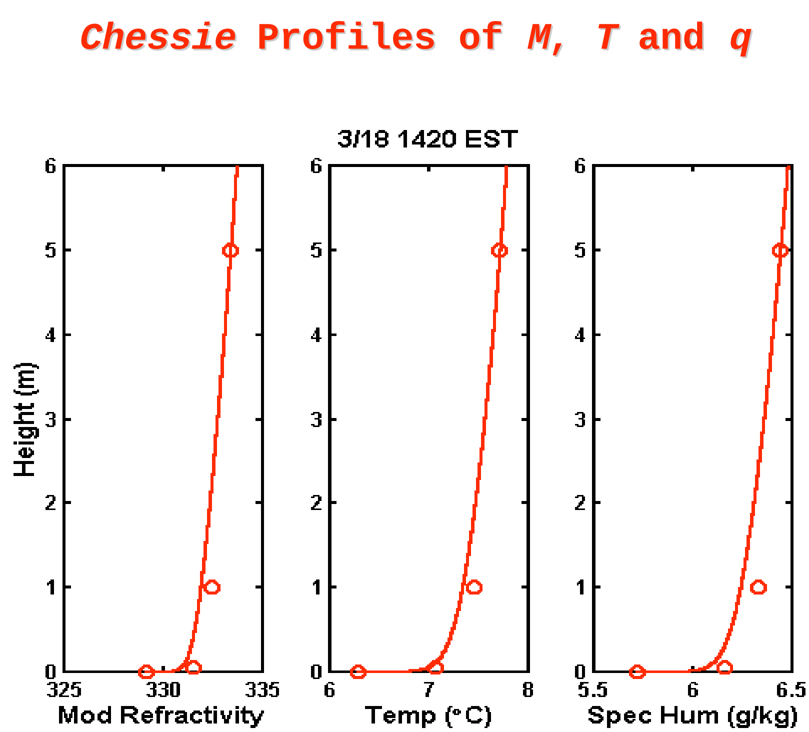

Figure 1. Comparison of catamaran (JHU/APL) near-surface profiles and bulk

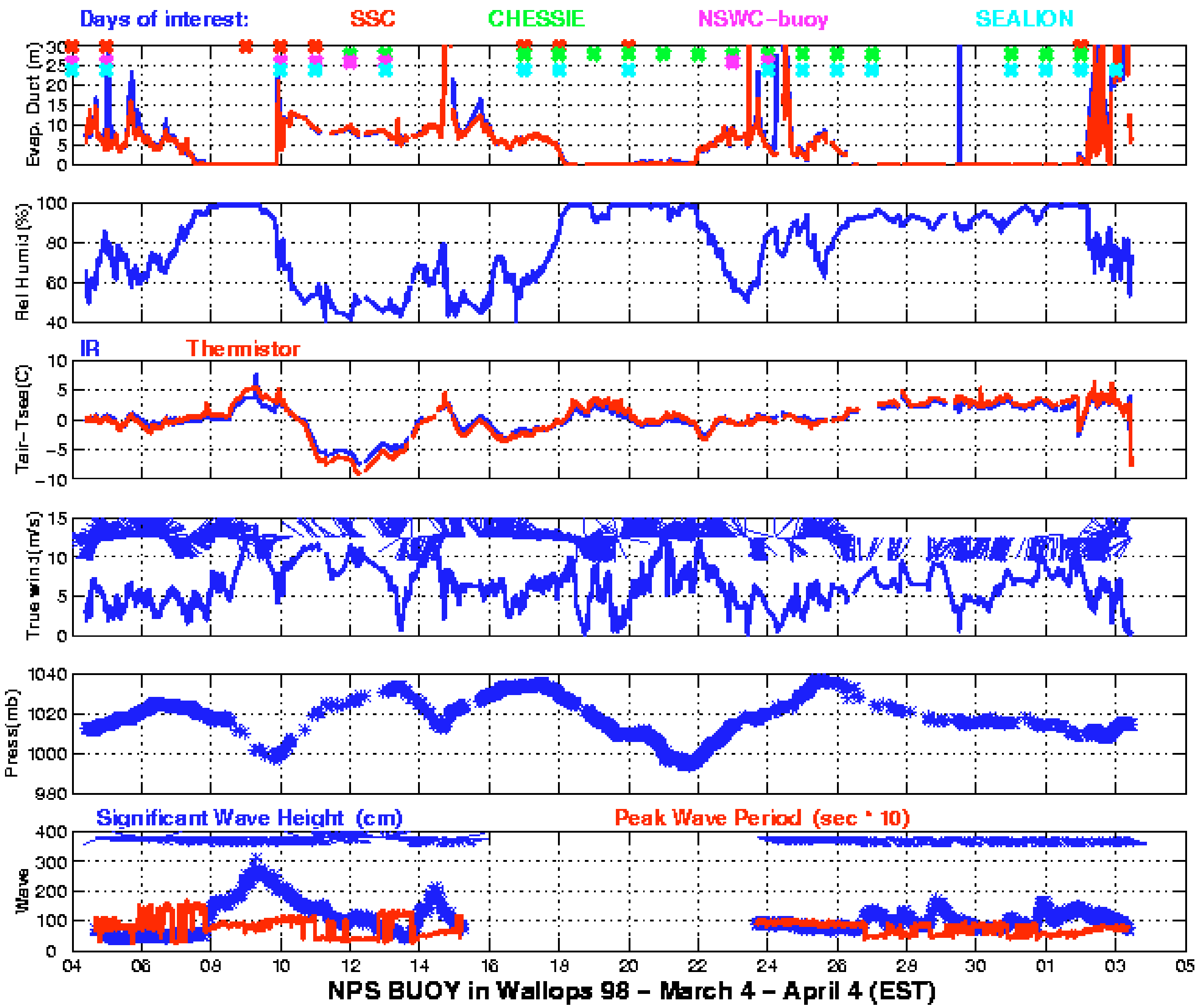

Figure 2. Time series from NPS Wallops '98 mean meteorology and wave buoy measurements and calculated evaporation duct heights. Color coded symbols in top panel indicate days of interest of